

Benchmarking: What's Your Building's Energy IQ?

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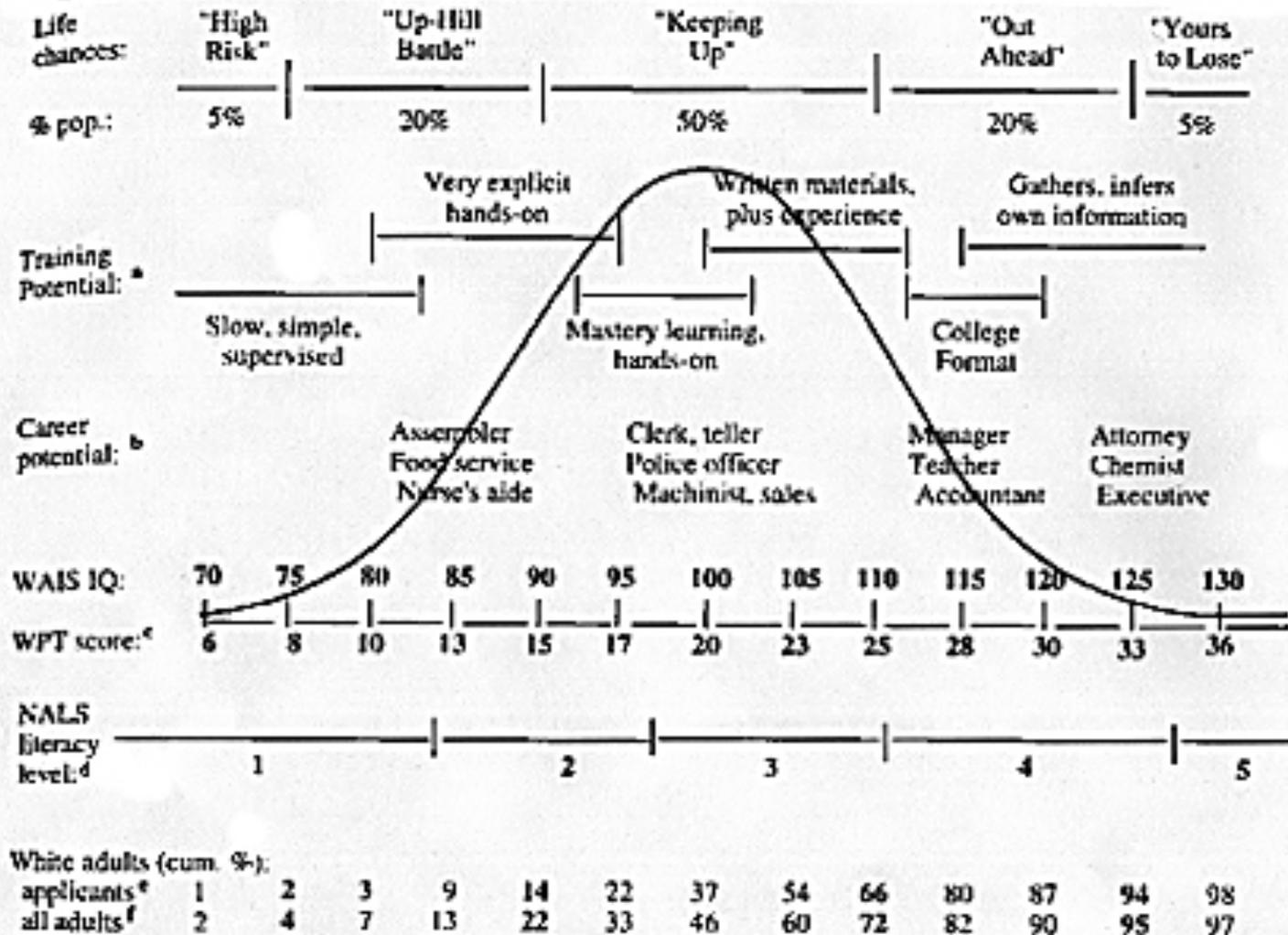
Presentation at *Sustaining the Future*

Hawaiian Electric Co., Sept. 26, 2003

Talk Outline

- ◆ What's Energy Benchmarking Anyway?
- ◆ Techniques
- ◆ Complications
- ◆ Applications
- ◆ Tools
 - For list, see: <http://poet.lbl.gov/cal-arch/links/>

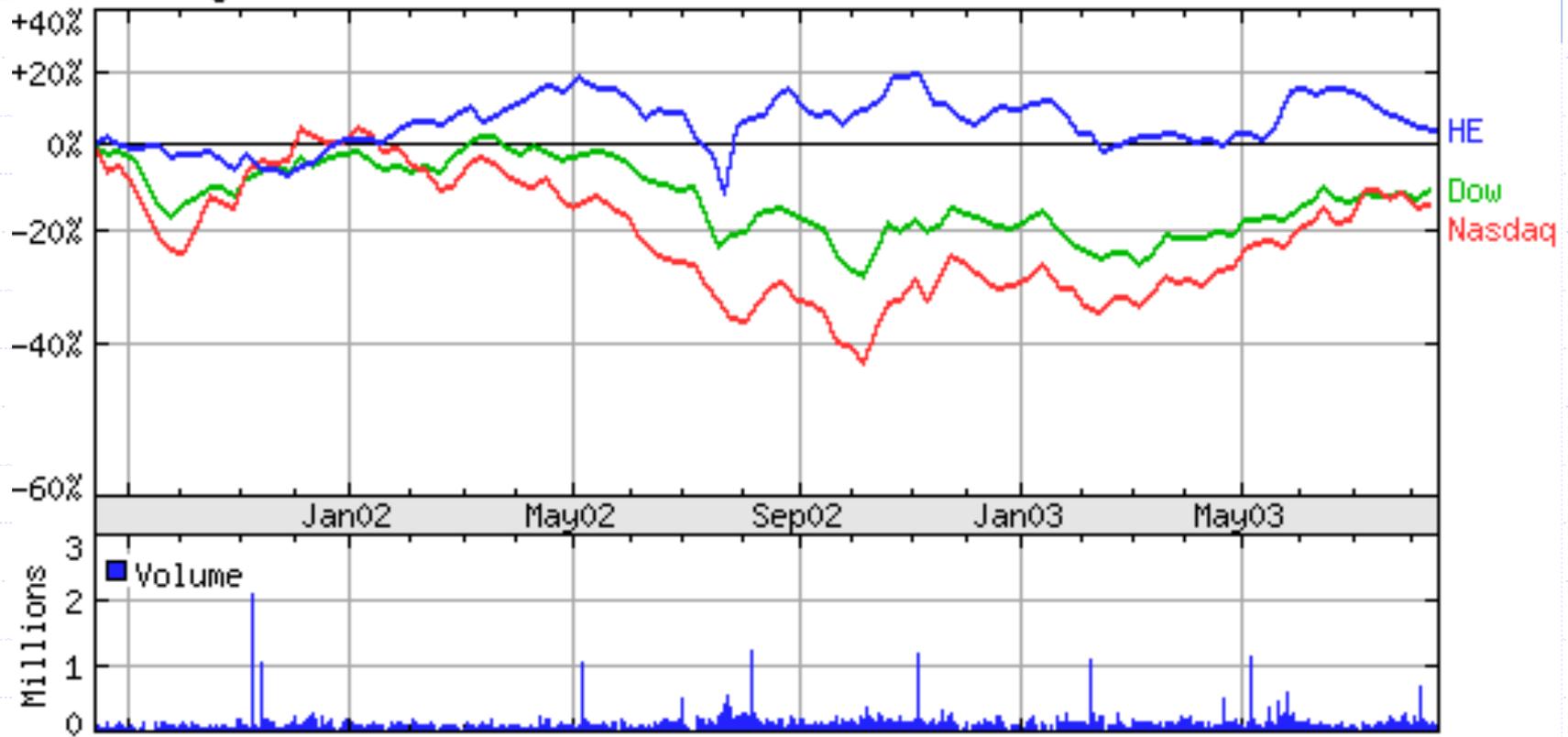
Familiar Benchmarks: IQ



Benchmarks are Everywhere

HAWAIIAN ELEC
as of 14-Aug-2003

Splits: ▼

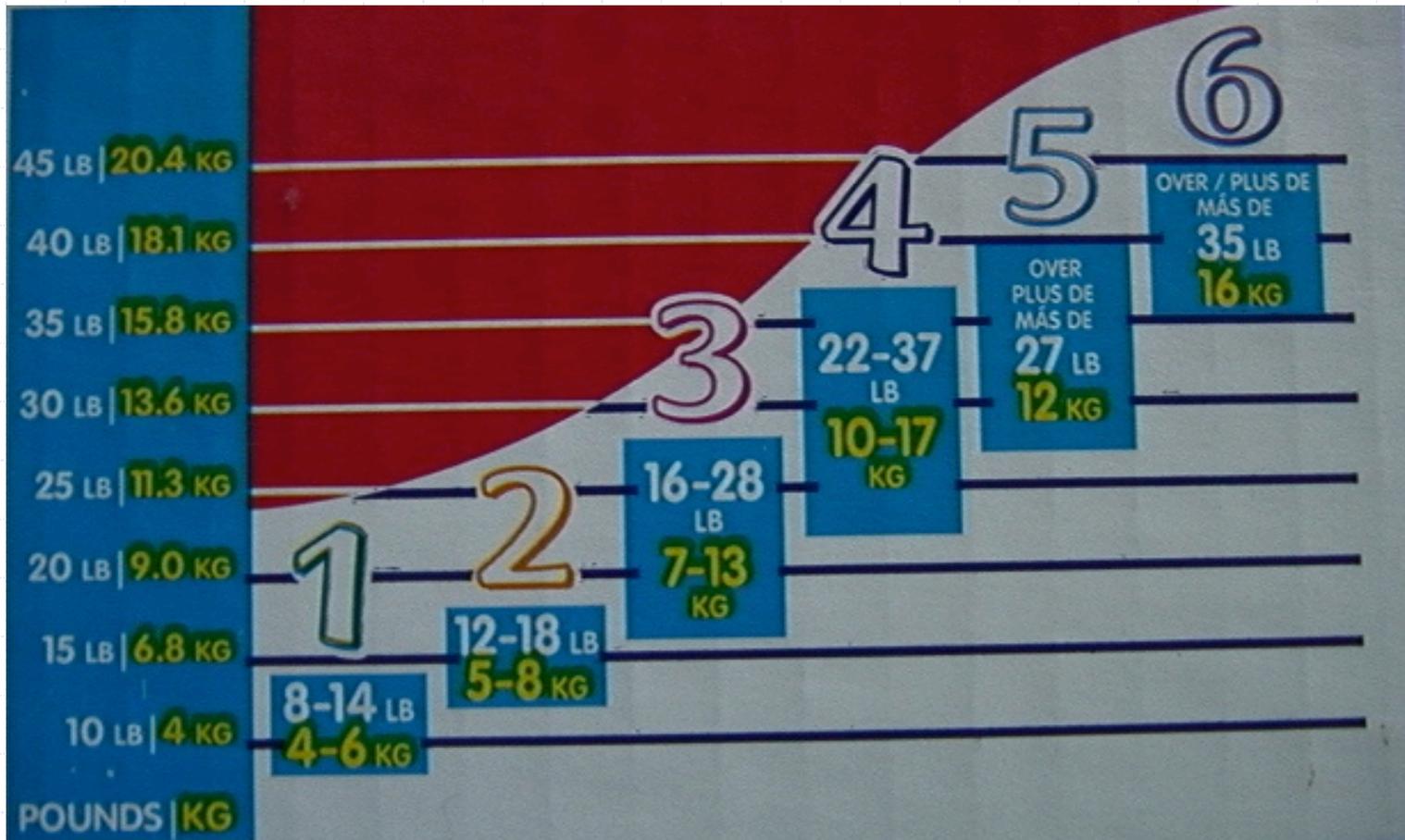


Copyright 2002 Yahoo! Inc.

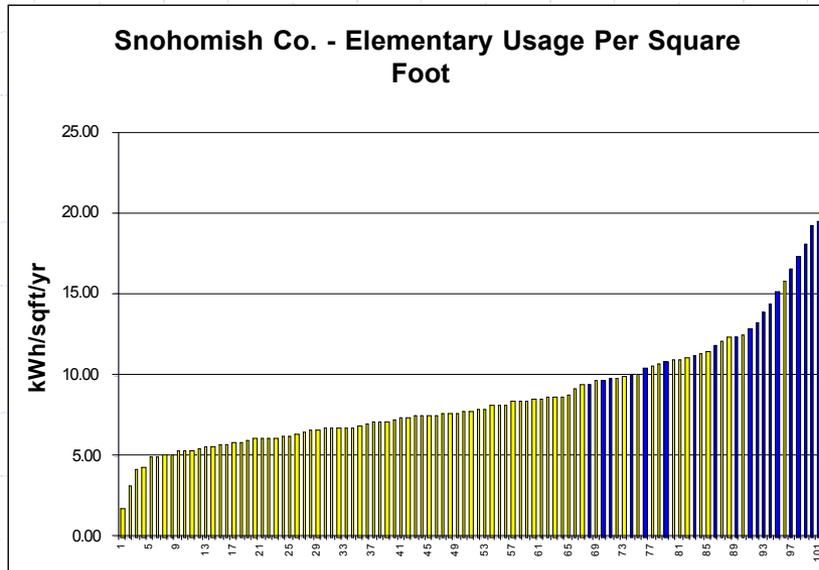
<http://finance.yahoo.com/>

“logit” Function of Child Weight

Nice chart; dubious value in real world



Why Benchmark?



- ◆ Establish baseline and track performance
- ◆ Validate design
- ◆ Identify maintenance and control problems
- ◆ Identify best practices; set goals or standards
- ◆ Identify savings potential
- ◆ Prioritize efforts
- ◆ Educate; Inspire!

Familiar Energy Benchmarks ...

...Fundamental differences in approach



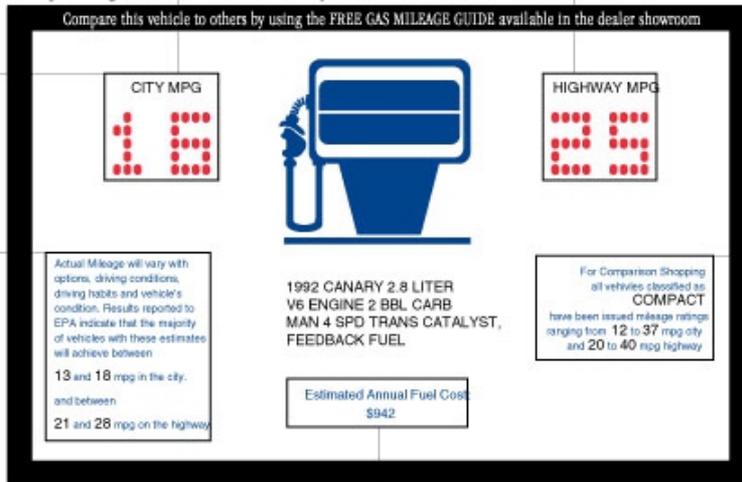
Sample Fuel Economy Label
(Attached to New Vehicle Window)

This is the average estimate for city driving

Use these two estimates to compare to other models

Compare this vehicle to others by using the FREE GAS MILEAGE GUIDE available in the dealer showroom

These numbers represent a range of fuel economy that most drivers achieve with this particular model.



This fuel cost is based on 15,000 mi/yr at \$1.20

These numbers represent the range of fuel economy for other models of this size class.

Based on standard U.S. Government tests

ENERGYGUIDE

Clothes Washer
Capacity: Standard
Top Loading

XYZ Corporation
Model(s) MP420L, XL12, KAA83

Compare the Energy Use of this Clothes Washer with Others Before You Buy.

This Model Uses **873 kWh/year**

Energy use (kWh/year) range of all similar models

Best Least Energy **257** | Best Most Energy **1818**

kWh/year (kilowatt-hours per year) is a measure of energy (electricity) use. Your utility company uses it to compute your bill. Only standard size, top loading clothes washers are used in this scale.

Clothes washers using more energy cost more to operate. This model's estimated yearly operating cost is:

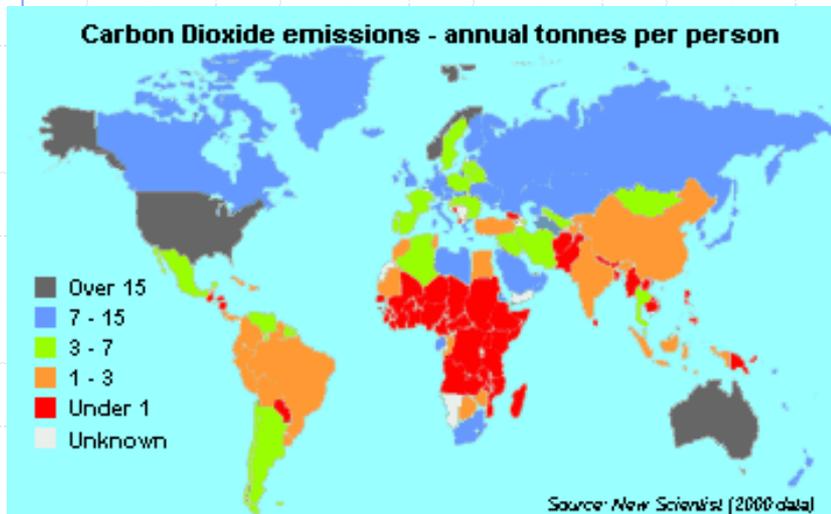
\$72 when used with an electric water heater | **\$28** when used with a natural gas water heater

Based on eight loads of clothes a week and a 1992 U.S. Government national average cost of \$0.254 per kWh for electricity and 58¢ per therm for natural gas. Your actual operating cost will vary depending on your local utility rates and your use of the product.

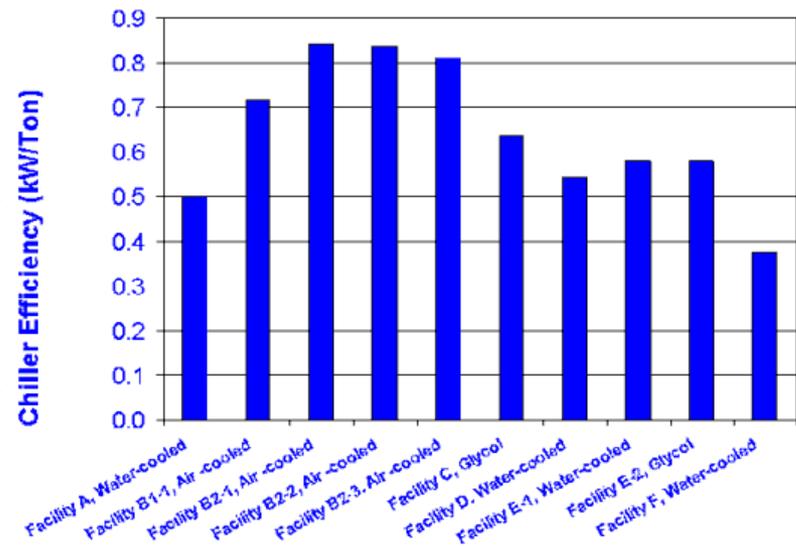
Manufacturer's Model(s) of this Model before estimates: MP420L-8.1, KAA83-8.1. Model(s) of similar size: KAA83-8.1.

Benchmarking Can Be Done at Any Scale

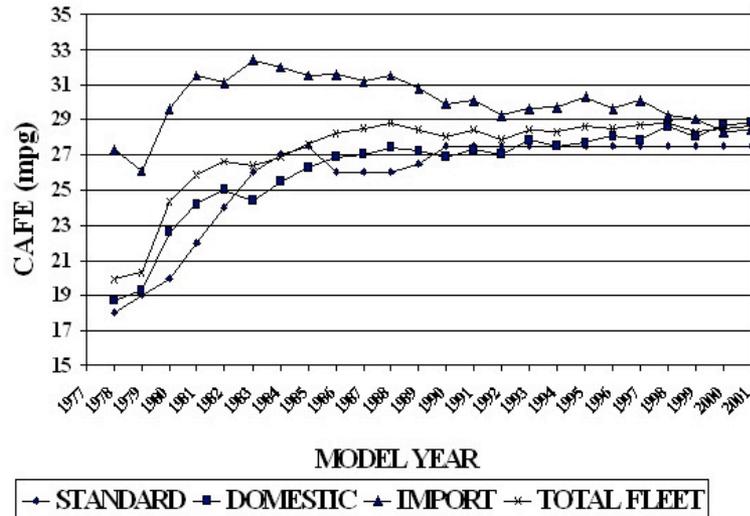
- Global CO₂/Capita



- Chiller efficiency

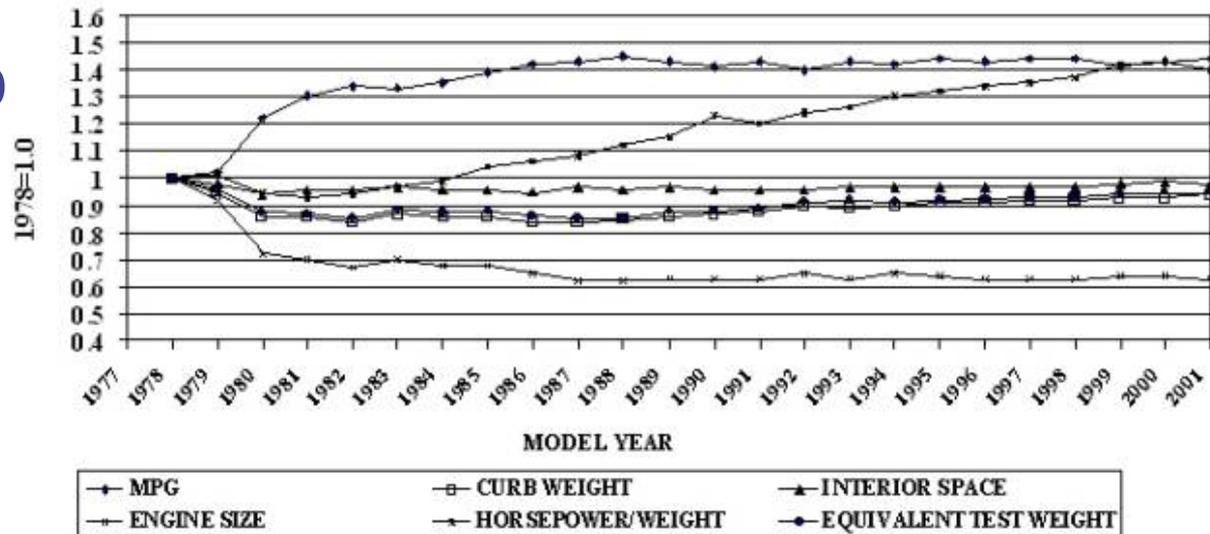


Choice of Benchmark Determines Conclusions



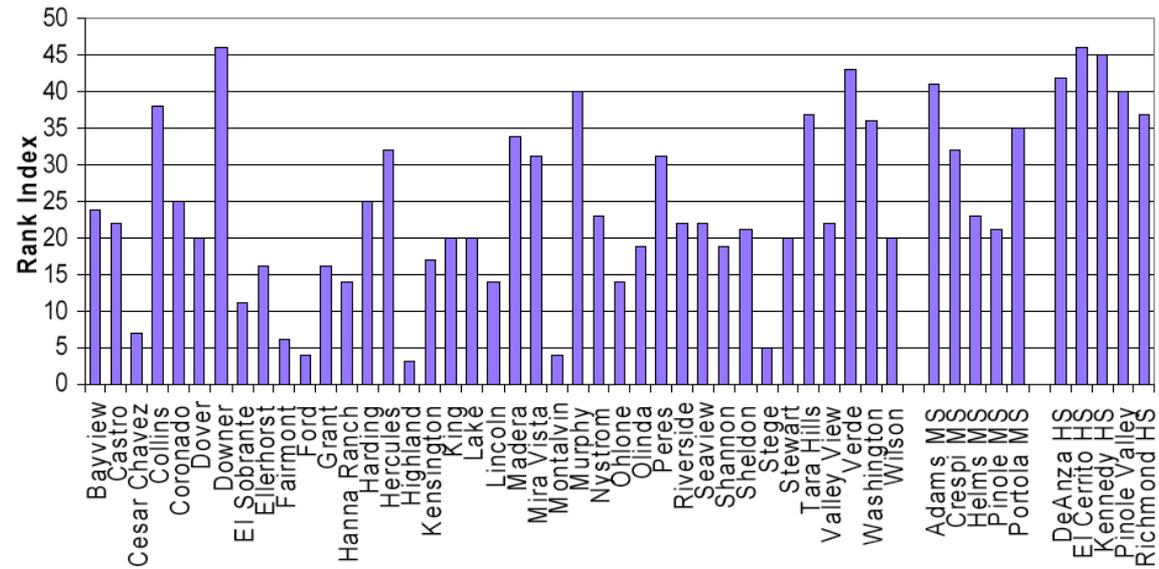
◆ Important to isolate sub-groups of interest

◆ Many ways to benchmark a given system

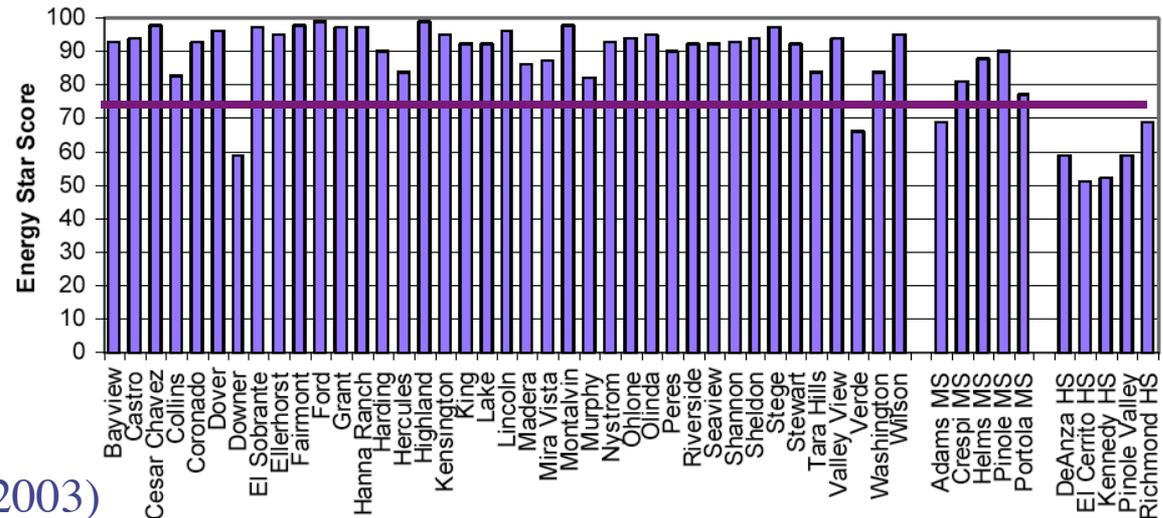


Choice of Benchmark Determines “Results” & Actions

Average Index of Various Indicators (energy/student, energy/sf, etc.)



ENERGY STAR Score (75 = “passing”)



Source: Norford, Palomera-Arias, and Ramsey (2003)

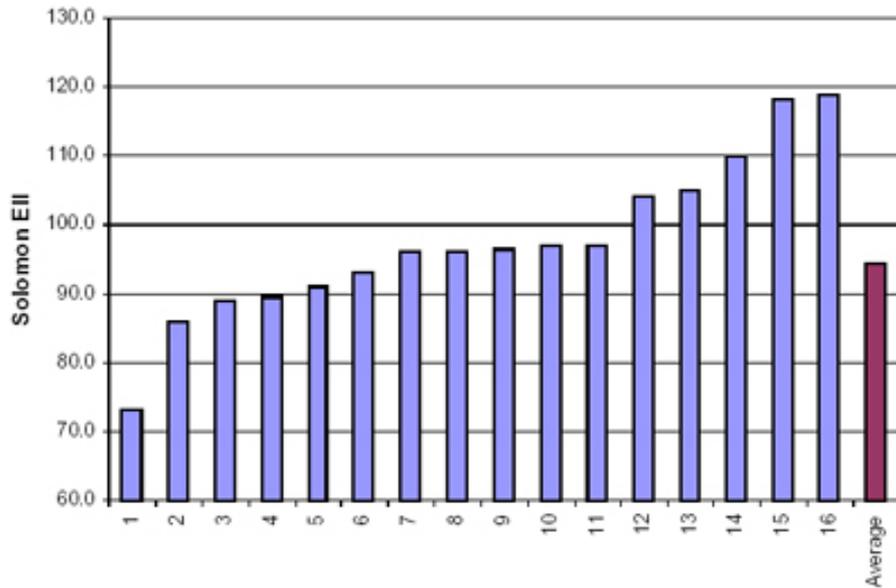
Approaches to Benchmarking

- ◆ Point-estimates (vs. population avg.)
- ◆ Statistical (bell curve; vs. population)
- ◆ Point-based (vs. best practice)
- ◆ Model-based (actual vs. efficient)
- ◆ Standardized (vs. test procedure)

Scope: self-referential; enterprise; stock

Timeframe: historic trends vs. current

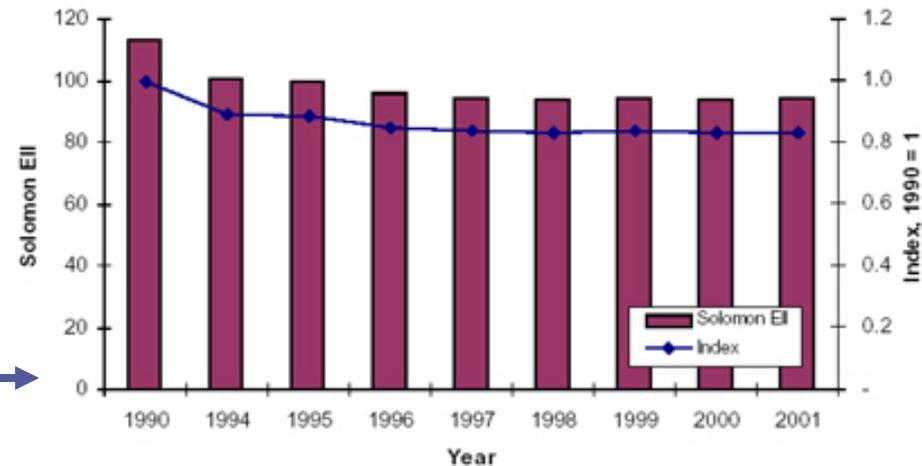
Lateral & Longitudinal: e.g. Canadian Oil Refineries



Solomon Energy Intensity Index of Participating Individual Refineries
Source: CIEEDAC, 2002.

Following “fleet-wide” trends over time

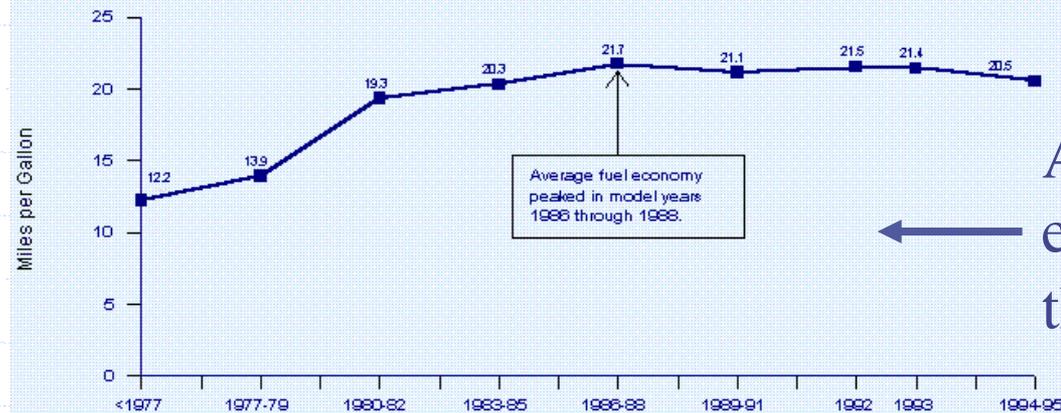
Comparing “peers” at one point in time



Average Refinery Energy Intensity based on a composite of Solomon EI for all known refineries.⁴

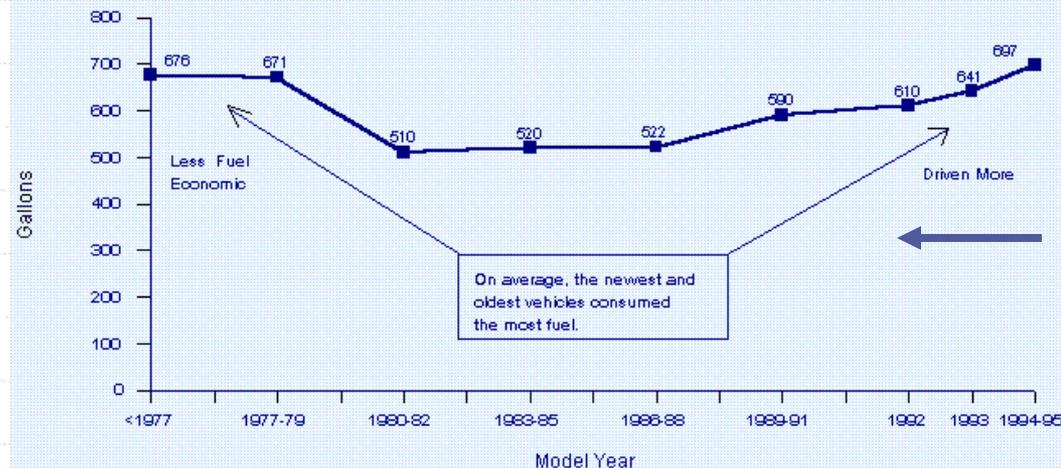
Decide What is Important Before Benchmarking

Figure 4.1 Average Fuel Economy of Residential Vehicles for Model Years Through 1995



Average US fuel economy increasing, then flat

Figure 4.9 Average Residential Vehicle Fuel Consumption per Vehicle for Model Years Through 1995

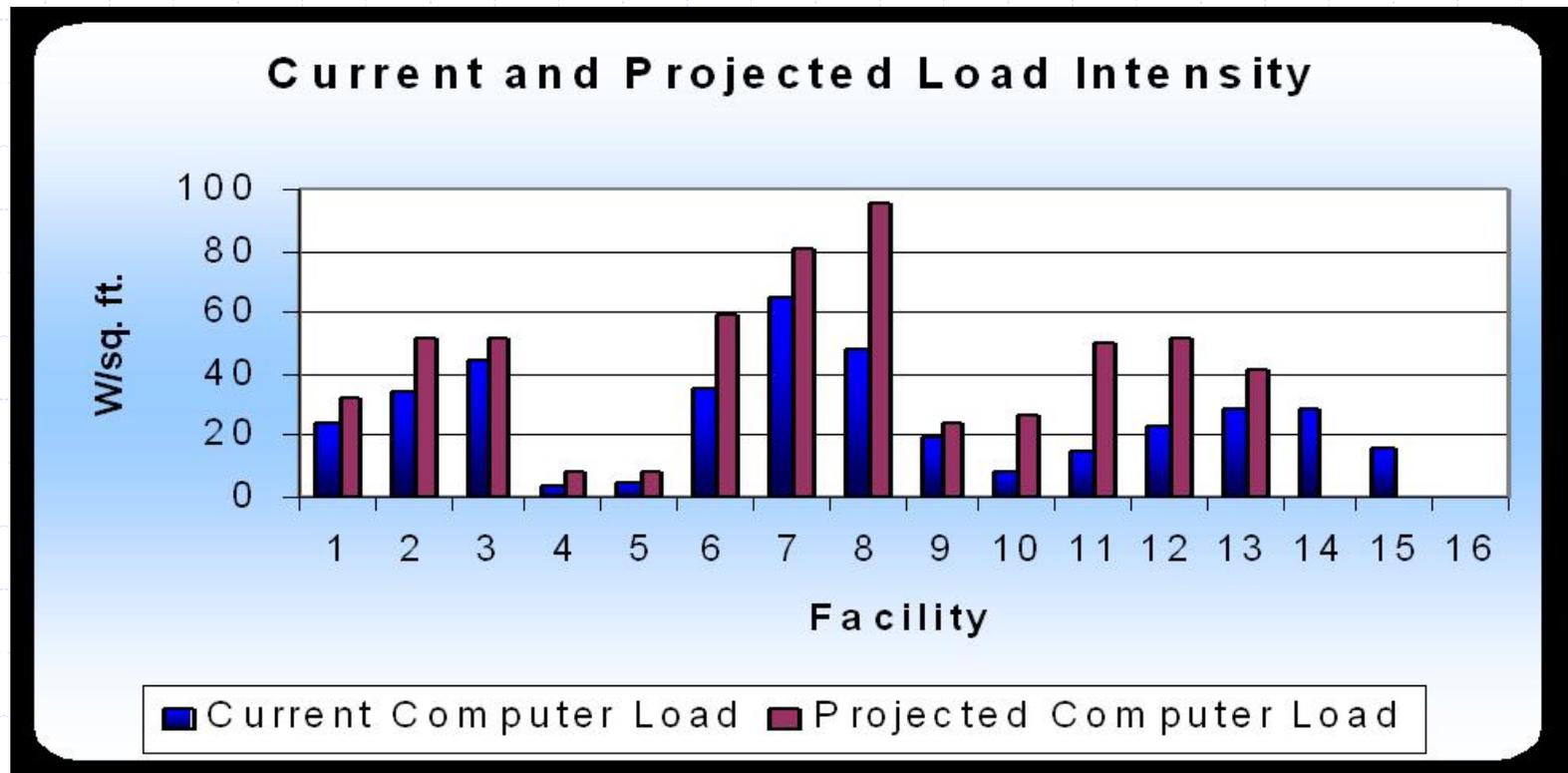


Average US vehicle fuel use declining then rising

“Reality Check”: Data Centers

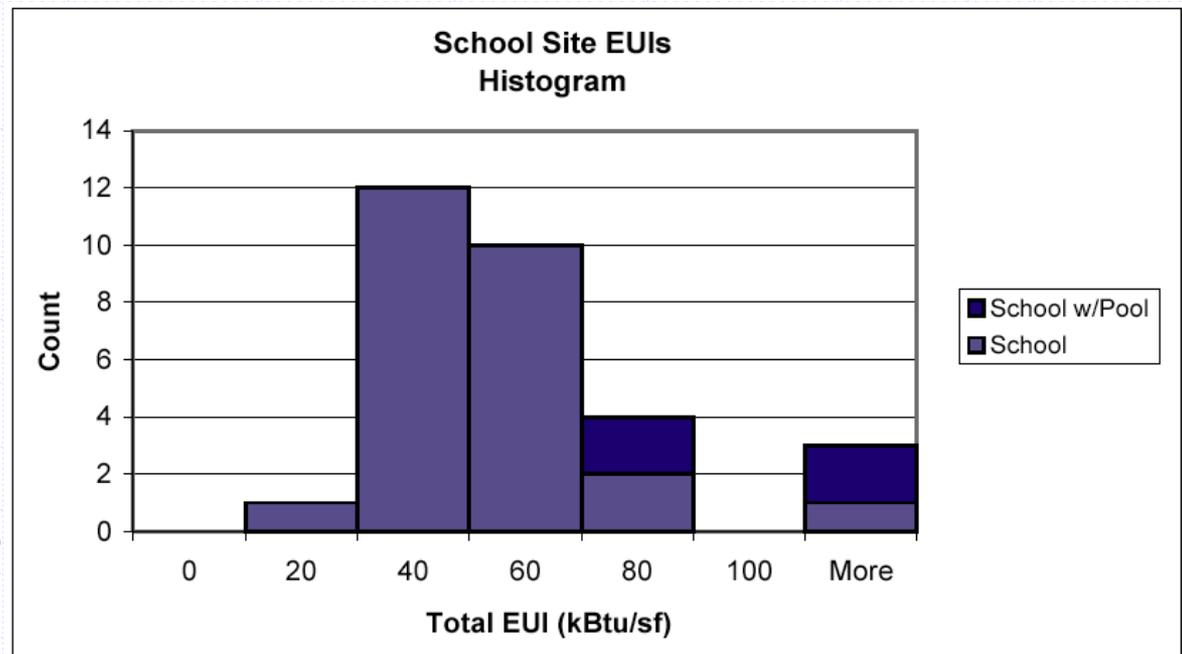
California Data Center owners claim a need of 250 W/ft²

Real data benchmarks the actual need between 10 and 100.



Caveats & Pitfalls

- ◆ Intensity does not equal efficiency
- ◆ Hard to avoid apples-and-oranges comparisons (want energy per unit of service)
- ◆ Normalization
 - weather
 - floor area
 - schedule
 - plug loads
 - indoor conditions
 - energy price



Examples from Hawaii

◆ Schools

- 32 Schools
- Average EUI: 5.9 kWh/ft²-year
- Range: 3.05 - 11.52 kWh/ft²-year

◆ Banks

- 49 Branches
- Average EUI: 20.07 kWh/ft²-year
- Range: 7.96 - 36.40 kWh/ft²-year

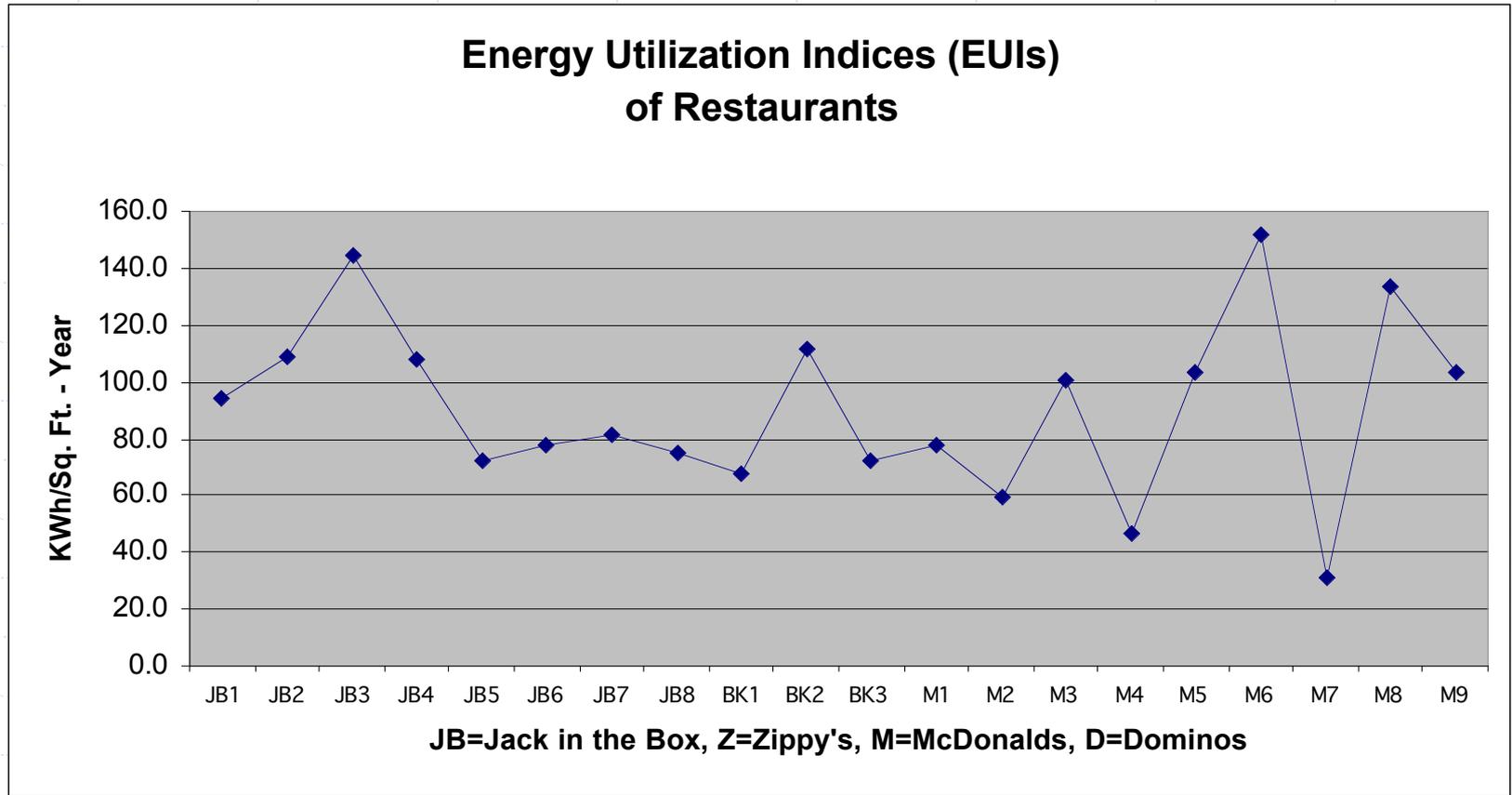
Source: HECO, Thomas D. Van Liew

Hawaii Commercial Buildings Benchmarking Study

- ◆ Offices: **22.82 kWh/ft²-y**
- ◆ Lodging: **16.14 kWh/ft²-y**
- ◆ Restaurants: **52.88 kWh/ft²-y**
- ◆ Grocery Store: **53.05 kWh/ft²-y**
- ◆ Education: **9.00 kWh/ft²-y**
- ◆ University of Hawaii: **13.82 kWh/ft²-y**
- ◆ Health Care: **24.83 kWh/ft²-y**
- ◆ Retail: **25.50 kWh/ft²-y**
- ◆ Apartments: **10.11 kWh/ kWh/ft²-y**
- ◆ Warehouse: **6.76 kWh/ kWh/ft²-y**
- ◆ Miscellaneous: **12.09 kWh/ kWh/ft²-y**

Source: HECO, Thomas D. Van Liew

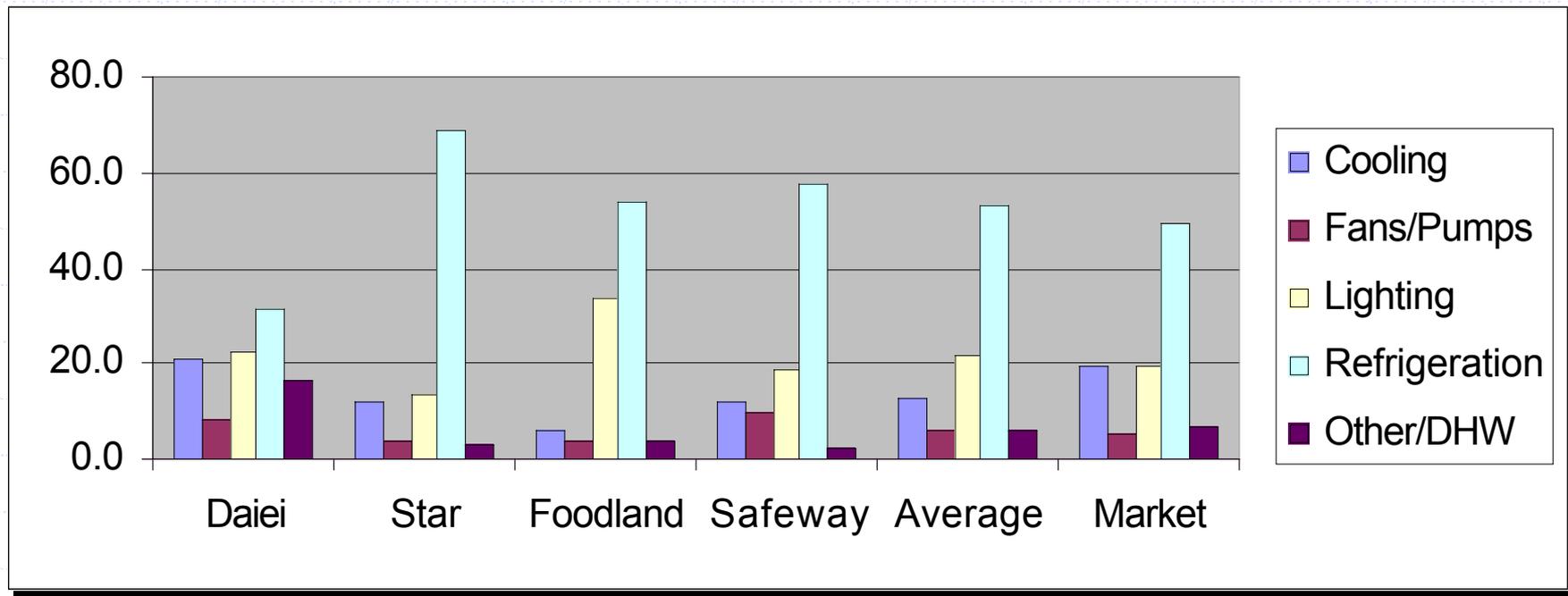
Fast Food Restaurant EUIs: Hawaii



Source: HECO, Thomas D. Van Liew

Grocery Store Energy Intensities

Hawaii Average = 70.9 kWh/ft²-year



Source: HECO, Thomas D. Van Liew

Energy Intensities

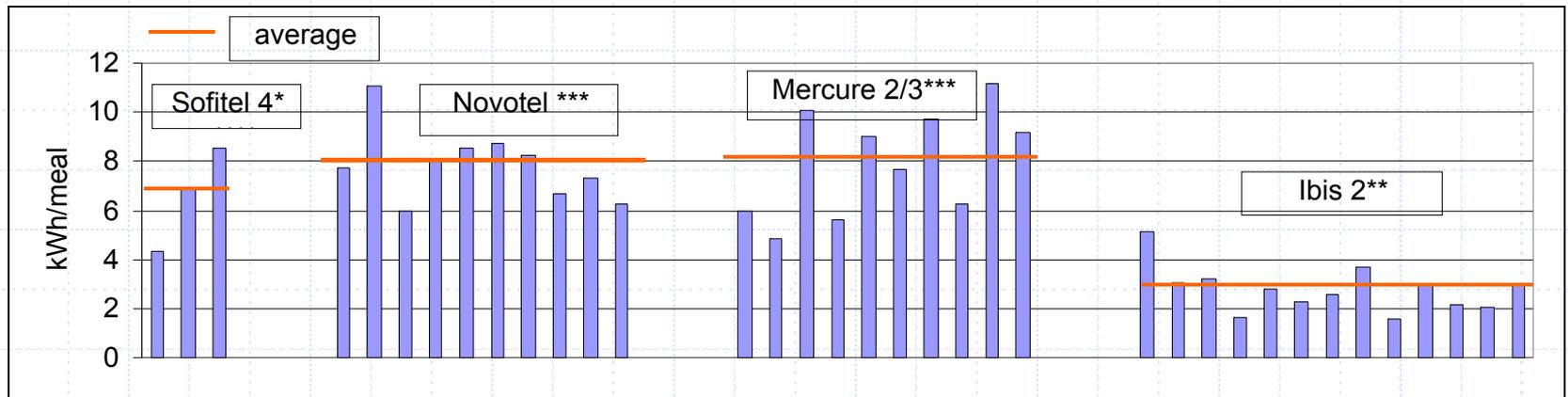
Energy per meal for 36 hotels, France

Std. Dev. 34%

27%

19%

32%

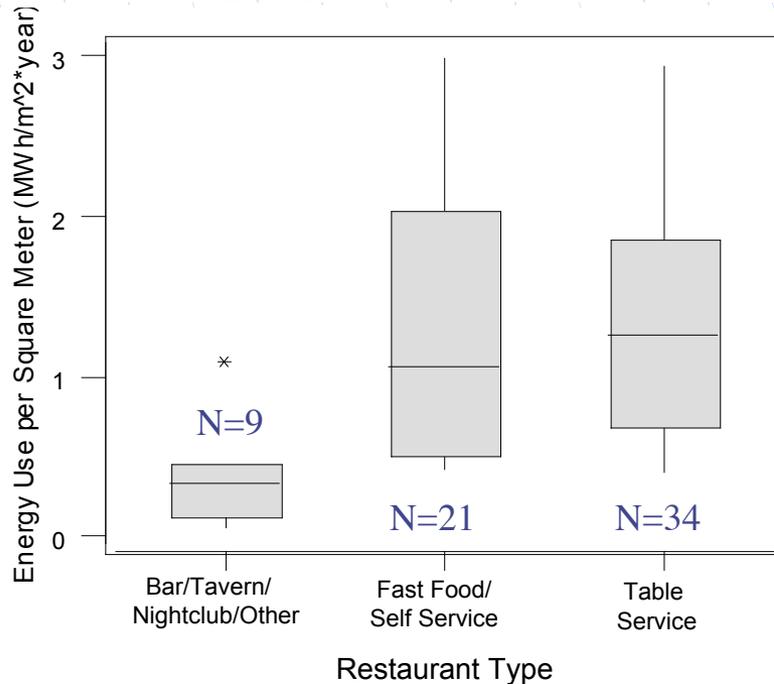


category of hotels	conservation kWh/meal	cooking kWh/meal	dishwashing kWh/meal	total kWh/meal	standard deviation
2**	0.44	2.08	0.25	2.77	0.94
2**/3***	3.81	3.89	0.25	7.95	2.18
3***	3.67	3.99	0.21	7.86	1.47
4****	2.53	3.92	0.13	6.58	2.13

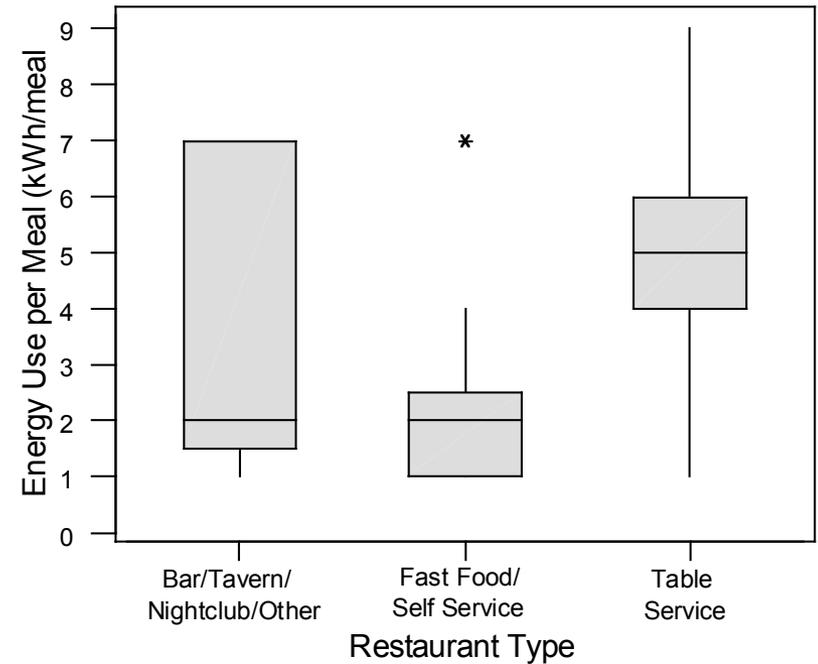
Source: Le Strat et al., (1999)

Choice of Indicator is Key

Energy per unit floor area



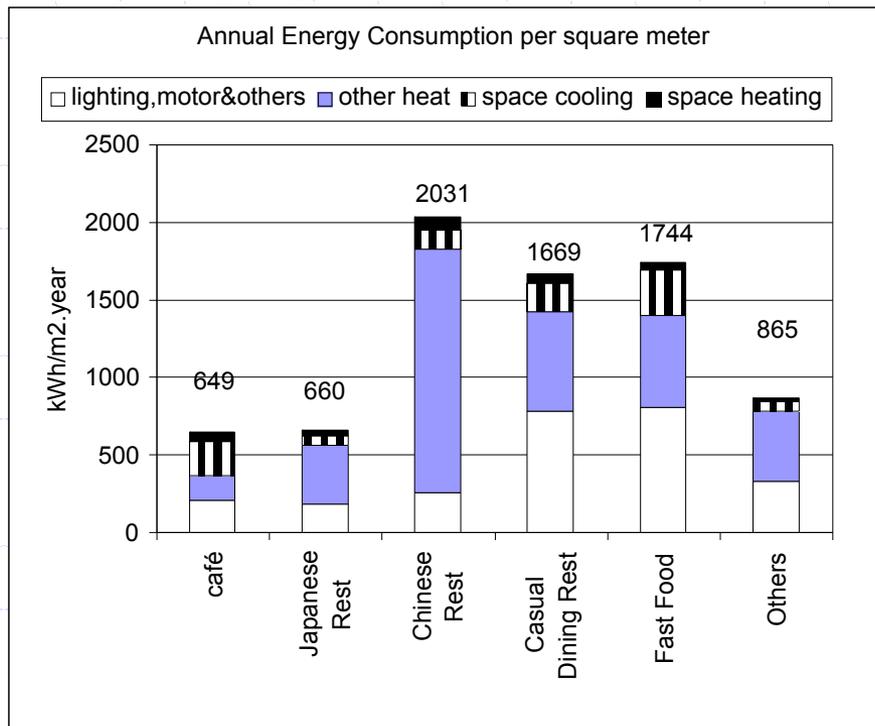
Energy per meal



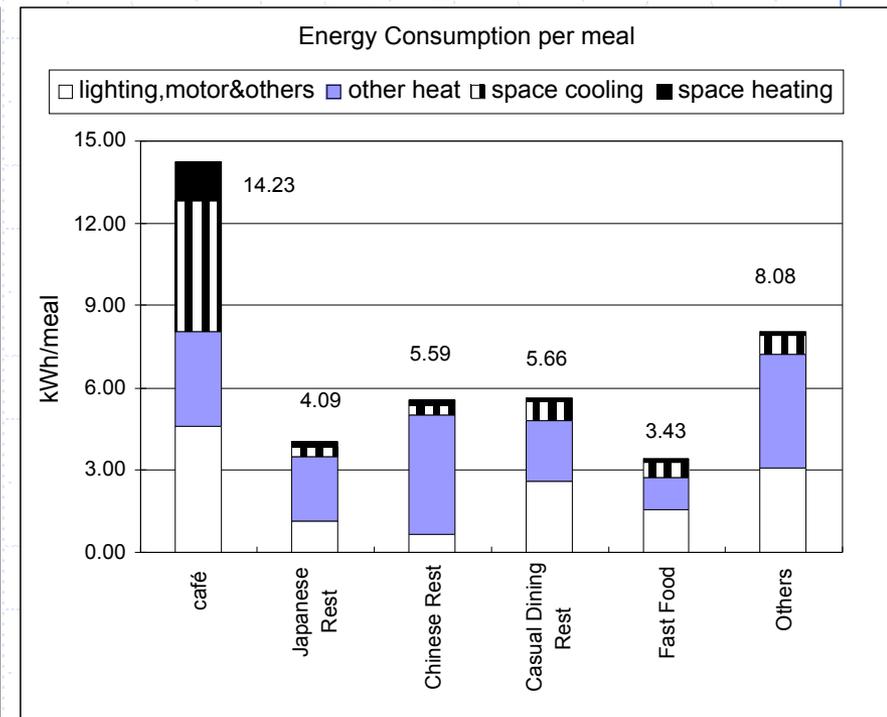
Source: 1996 California Commercial End Use Survey
(Restaurant energy)

Choice of Indicator is Key

Energy per unit floor area

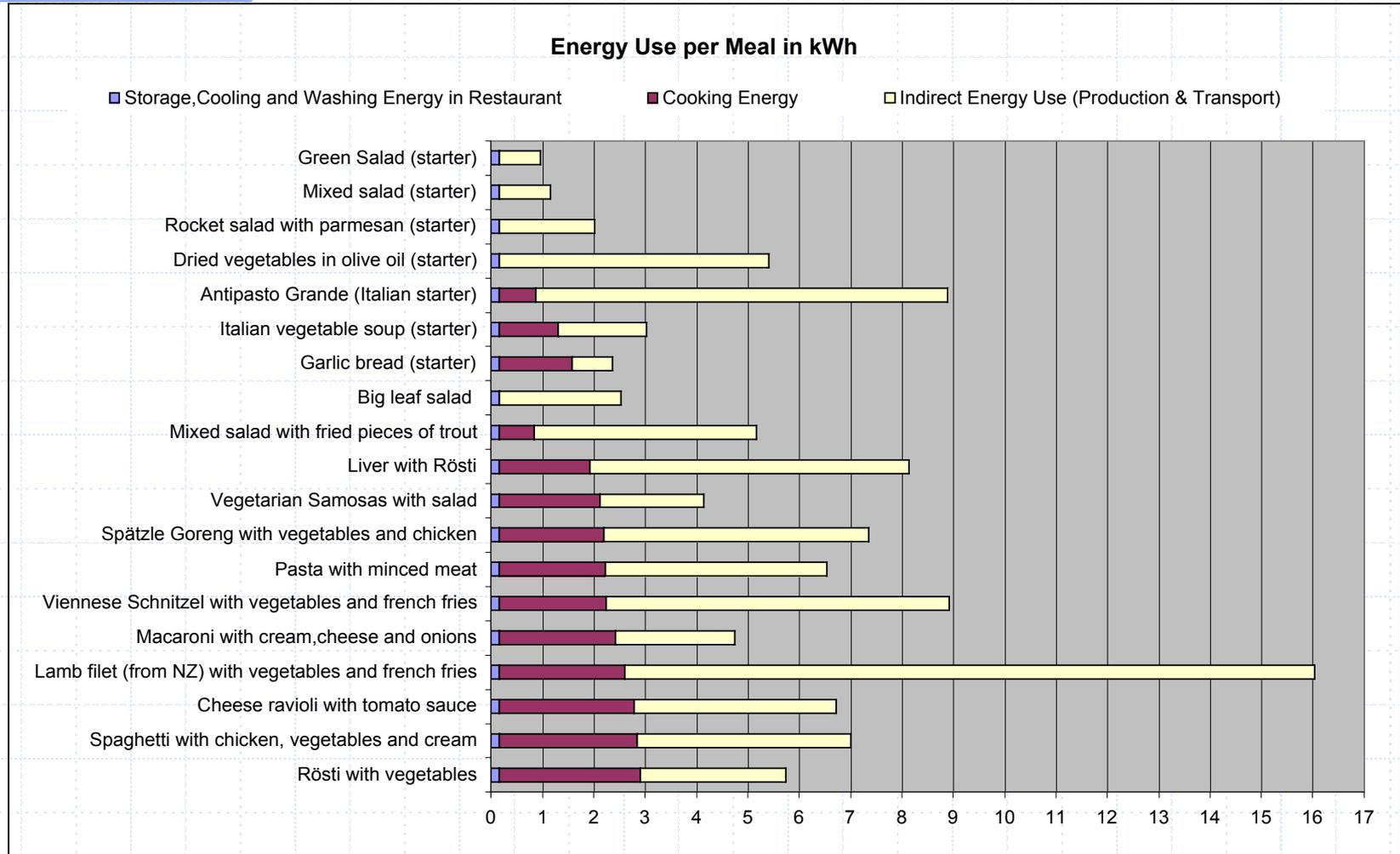


Energy per meal



Source: The Energy Data and Modeling Center, 2001

Beyond “Apples & Oranges”: Pippins and Granny Smiths

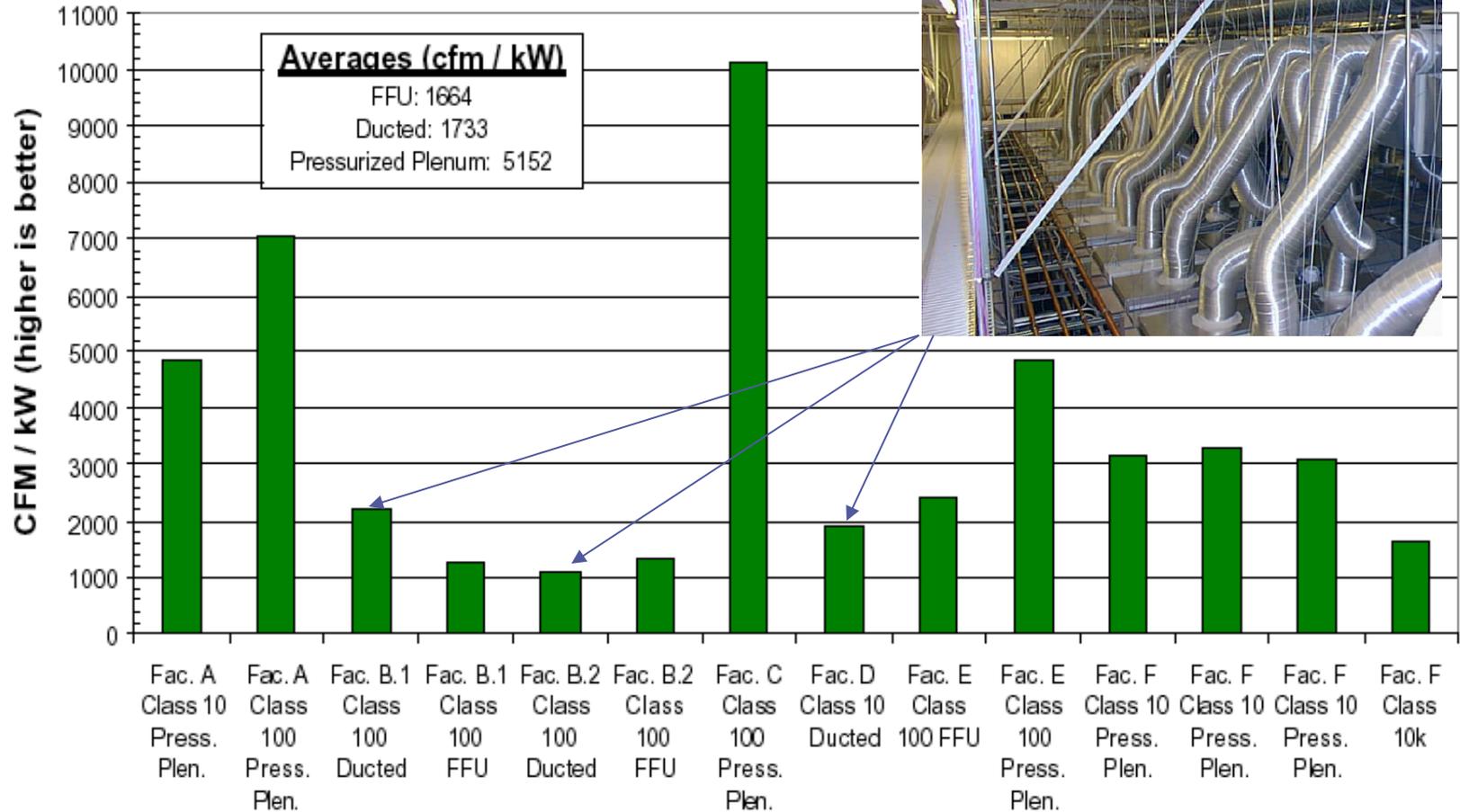


Data for Switzerland. Source: Balmer and Hintermann, 2000

Cleanroom Energy Metrics

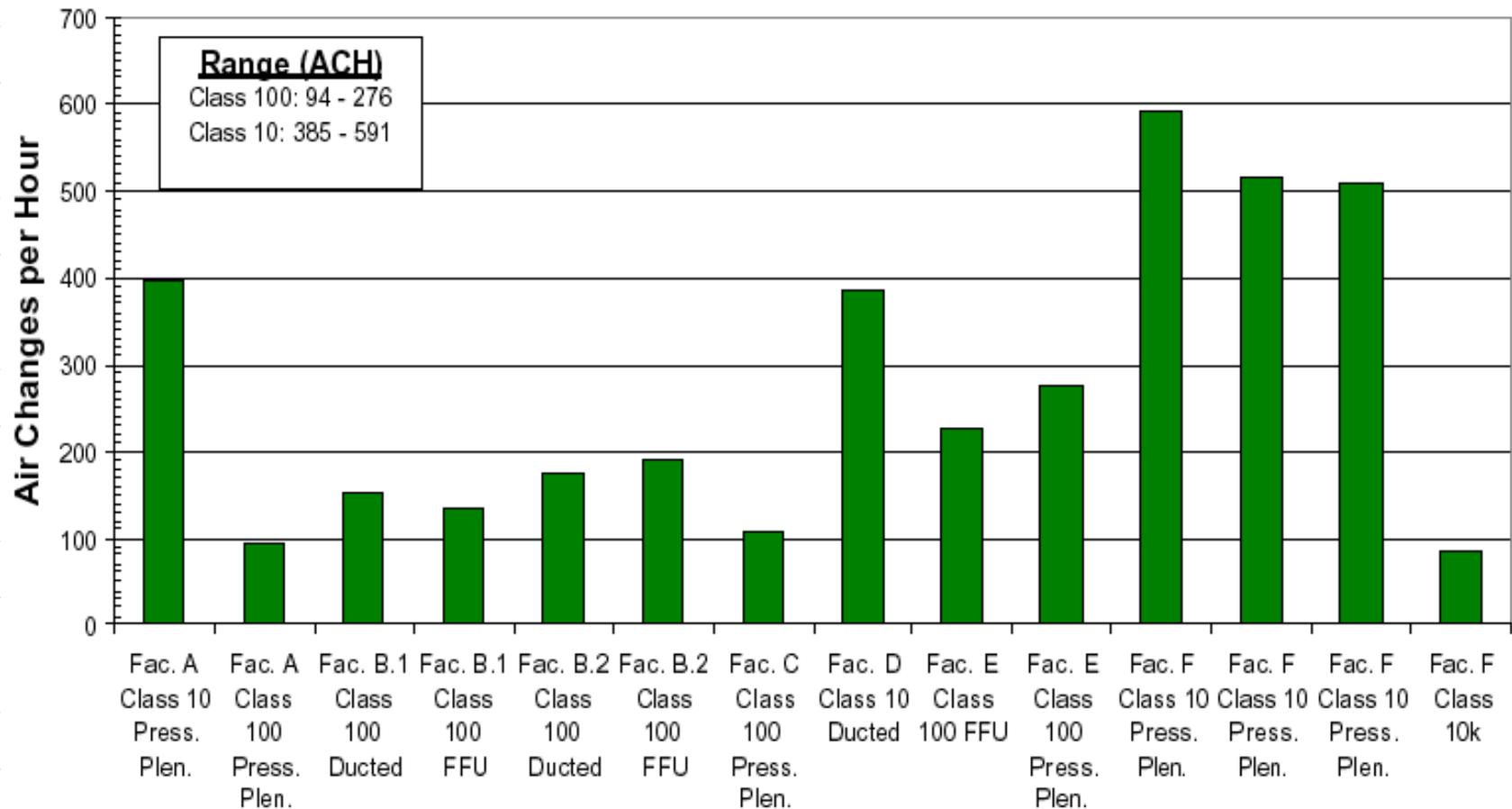
•Recirculation air handler efficiency	•cfm/kW
•Makeup air handler efficiency	•cfm/kW
•Annual energy cost per cleanroom square foot	•\$/ft ²
•Annual fuel usage	•MBtu/ft ² -yr
•Annual electricity usage	•kWh/ft ² -yr
•Annual energy usage	•MBtu/ft ² -yr
•Makeup air	•cfm/ft ²
•Recirculation air	•cfm/ft ² or ach
•Chiller efficiency	•kW/ton
•Tower efficiency	•kW/ton
•Condenser water pump efficiency	•kW/ton
•Chilled water pump efficiency	•kW/ton
•Total chilled-water plant efficiency	•kW/ton
•Hot water pumping efficiency	•kW/MBtu
•Cooling load density	•ft ² /ton

Delivery of Service Levels



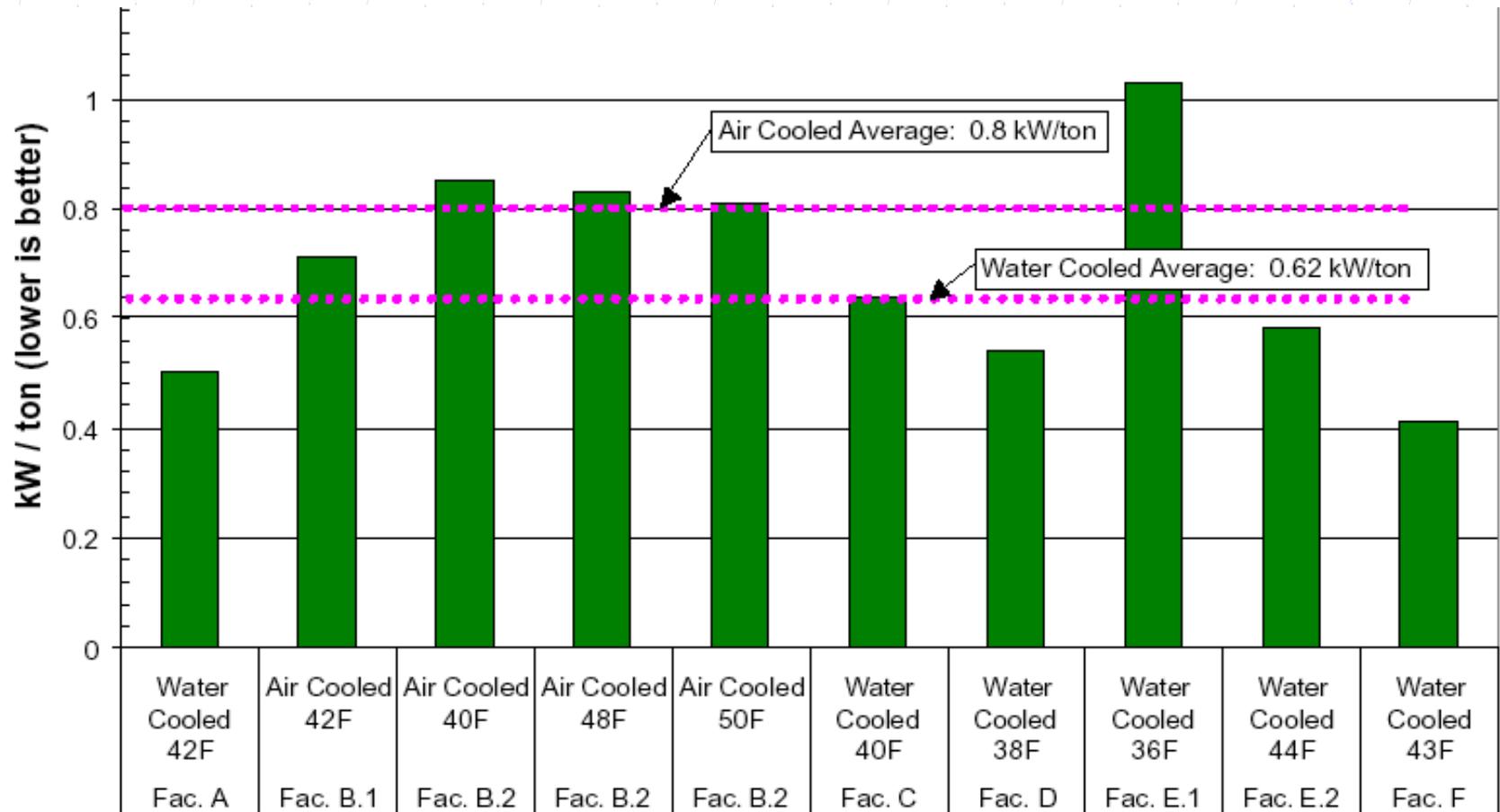
Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

Some “Energy” Benchmarks Don’t Even Include Energy



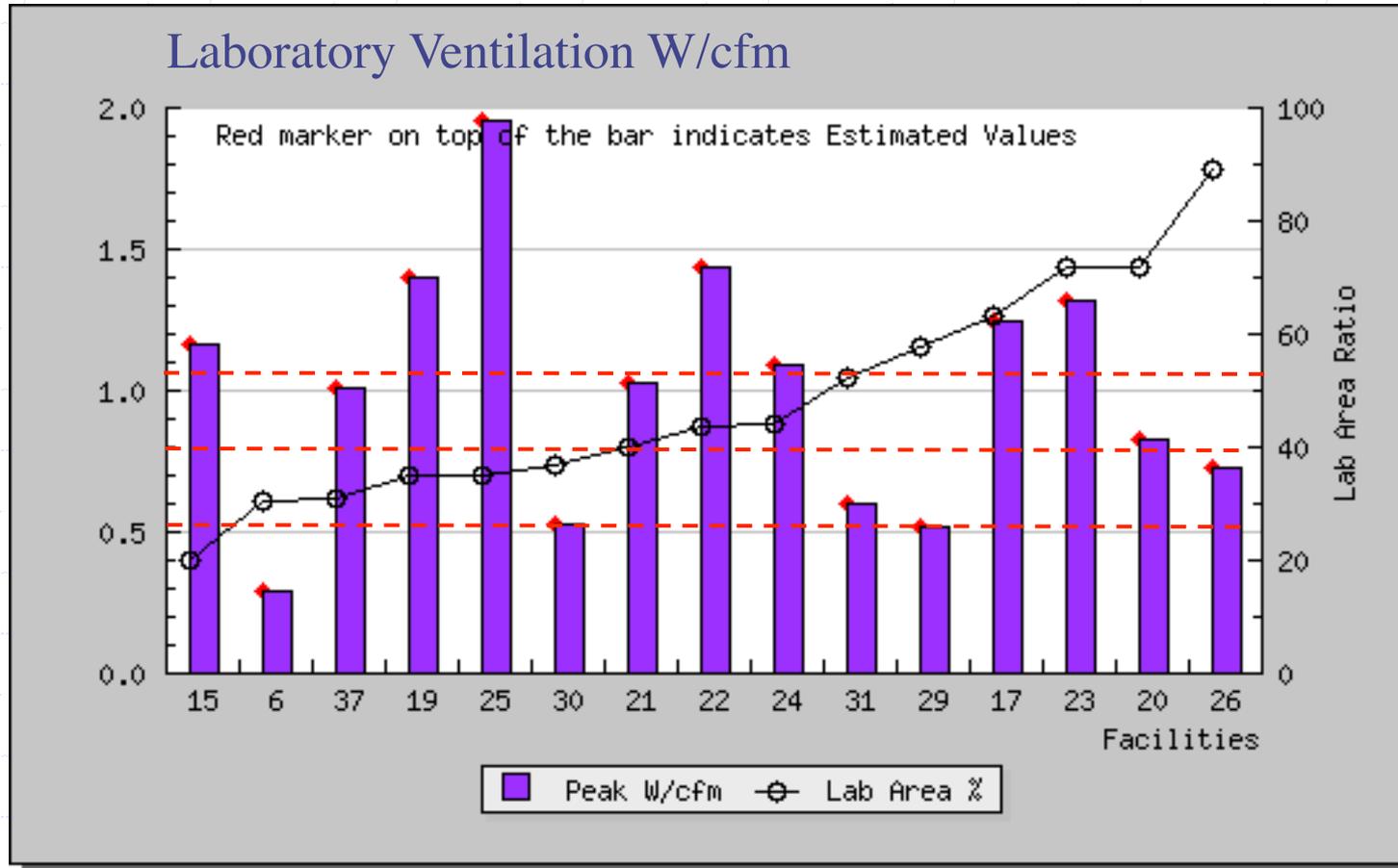
Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

Cleanroom Chiller Efficiencies



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

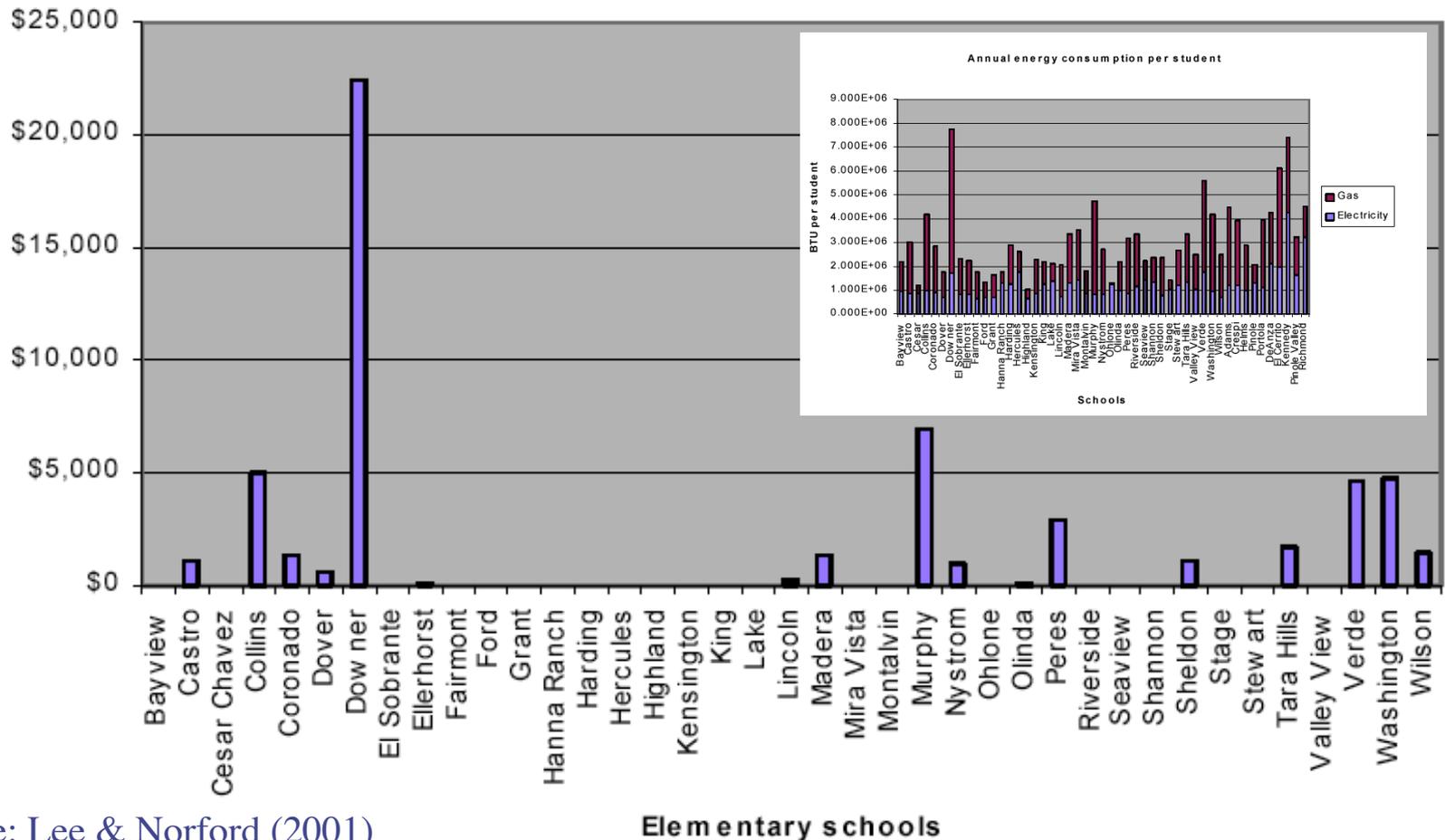
From Benchmarking to Best Practices



Standard, good, better benchmarks as defined in
“How-low Can You go: Low-Pressure Drop Laboratory Design”
by Dale Sartor and John Weale, ASHRAE Journal

Benchmarks as Screening Tool

Annual gas expenditure saving if brought to the median value



Source: Lee & Norford (2001)



- PRODUCTS**
- HOME IMPROVEMENT**
- NEW HOMES**
- BUSINESS IMPROVEMENT**
- PARTNER RESOURCES**
- + WHAT IS ENERGY STAR?
- + NEWS ROOM

[Home](#) > [Home Improvement](#) > Home Energy Yardstick

Home Energy Yardstick

[Home Energy Advisor](#)

Improve Your Home

- + [Home Sealing](#)
- + [Heating & Cooling](#)

[Common Home Improvements](#)

Home Energy Performance Results

Energy Performance

[Printable](#)

Your score is 7.7 out of 10

This means that about **23%** of U.S. homes use less energy than yours.

Improving your score from **7.7** to **8.7** is approximately a 12% reduction in energy use and could save you up to **\$270** a year on energy costs.

Environmental Performance

Annual pollution from energy use in your home is equivalent to the emissions of **1.9** cars. Improving your score from **7.7** to **8.7** would reduce your emissions by 12%.

About Your Home & Energy Use [\[Edit Info\]](#)

About Your Home

- Zip Code: 96801
- People Living in Home: 4
- Square Footage of Home: 2000
- Home Built: 2000s
- Electric Well Pump? No
- Heating Degree Days: 0
- Cooling Degree Days: 4401

Improving your Performance

To improve your score and save energy you need help to identify the most cost effective improvements for your home. Here are some suggestions:

[Use the Home Energy Advisor to identify the five most cost effective ways for you to save money and energy.](#)

[Locate an Energy Management Consultant](#)

[Find ENERGY STAR labeled products for your home.](#)

ENERGY STAR Building Label

Normalized Benchmark Data

	<u>ENERGY STAR</u>	<u>Your Building</u>
Benchmarking Score:	75	77
Energy Intensity:		
Site (kBtu/ft ² -yr):	57	55
Source (kBtu/ft ² -yr):	171	166
Emissions:		
CO ₂ (1000 lbs/yr):	21,154	20,527
SO ₂ (1000 lbs/yr):	140	136
NO _x (1000 lbs/yr):	34	33
Energy Cost:		
(\$):	842,161	817,189
(\$/ft ² -yr):	1.33	1.29

Indoor Environment Criteria

INDOOR AIR POLLUTANTS CONTROLLED?
ADEQUATE VENTILATION PROVIDED?
THERMAL CONDITIONS MET?
ADEQUATE ILLUMINATION PROVIDED?

PASS
PASS
PASS
PASS

Professional Verification

Jason Jeter, Professional Engineer
Jeter, James and Jones Engineering
Street Address: 1701 Irving Street
City, State: Washington, DC 20036
Phone Number: 202-123-1234



Labs21 Benchmarking Tool

Data Input

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: http://www.dc.lbl.gov/Labs21/StepThreeP3.php

LABS FOR THE 21ST CENTURY

benchmarking

step one of four - login
 step two of four - enter facility name and year of data
step three of four - enter data for the facility
 step four of four - review / edit entered data

* Indicates Required Input

Data / Facility Information	
User	LBNL
Organization	Lawrence Berkeley National Laboratory
Facility chosen	Bldg2.AdvancedMaterialLab
Year chosen	2001

General Facility	
Street Address*	One Cyclotron Road
Location*	Berkeley, CA
Zip Code (5 digit)*	94720
Lab Use*	Research/Development
Lab Type*	Combination/Others
Lab Category*	Combination/Others
Number of Building(s)	1
Gross Area (sq. ft.)*	85761

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: http://www.dc.lbl.gov/Labs21/StepThreeP3.php

Energy Use	Measured	Estimated
Annual Energy Utility Cost (\$)*	231000	<input type="radio"/>
Annual Heating Energy (therms)*	124800	<input type="radio"/>
Does facility use CHP (Cogen) system?	No	<input type="radio"/>
Annual Electric Use (kWh)		
Total*	2526000	<input type="radio"/>
Ventilation	1010000	<input type="radio"/>
Cooling Plant (including campus chilled water, if any)	298000	<input type="radio"/>
Lighting	460000	<input type="radio"/>
Process/plug	1150000	<input type="radio"/>
Peak Demand (kW)		
Total*	478	<input type="radio"/>
Ventilation	0	<input type="radio"/>
Cooling Plant (including campus chilled water, if any)	0	<input type="radio"/>
Lighting	0	<input type="radio"/>
Process/plug	0	<input type="radio"/>

System	Measured	Estimated
Peak Cooling Load (Tons)	0	<input type="radio"/>
Average Cooling Load (Tons) (Total annual cooling ton-hours divided by 8760)	0	<input type="radio"/>
Cooling Plant Capacity (Tons)	500	<input type="radio"/>
Peak CFM (Sum of exhaust, supply, and recirculating fans)	0	<input type="radio"/>
Average CFM (Sum of exhaust, supply, and recirculating fans)	0	<input type="radio"/>

Labs21 Benchmarking Tool Analysis

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: <http://www.dc.lbl.gov/Labs21/CompareData.php?UserID=2>

LABS FOR THE 21ST CENTURY

benchmarking

Choose Metrics and Filtering Criteria

[More Information](#)

User: **LBNL**
 Organization: **Lawrence Berkeley National Laboratory**

Please specify the metric criteria -

System: Total Building
 Energy / Efficiency Metric: BTU/sf-yr (site)

Please specify the filtering criteria -

1. Lab Area / Gross Area ratio is greater than or equal to 0.00 and is less than or equal to 0.99

2. Occupancy

- Standard (≤ 14 hours)
- High (> 14 hours)
- Both (all data)

3. Climate [Climate Code, Climate Type, Representative City]

[\(To view the map of climatic distribution\)](#)

<input checked="" type="checkbox"/> 1A, Very Hot - Humid (Miami, FL)	<input checked="" type="checkbox"/> 2A, Hot - Humid (Houston, TX)
<input checked="" type="checkbox"/> 2B, Hot - Dry (Phoenix, AZ)	<input checked="" type="checkbox"/> 3A, Warm - Humid (Memphis, TN)
<input checked="" type="checkbox"/> 3B, Warm - Dry (El Paso, TX)	<input checked="" type="checkbox"/> 3C, Warm - Marine (San Francisco, CA)
<input checked="" type="checkbox"/> 4A, Mixed - Humid (Baltimore, MD)	<input checked="" type="checkbox"/> 4B, Mixed - Dry (Albuquerque, NM)
<input checked="" type="checkbox"/> 4C, Mixed - Marine (Salem, OR)	<input checked="" type="checkbox"/> 5A, Cool - Humid (Chicago, IL)
<input checked="" type="checkbox"/> 5B, Cool - Dry (Bosie, ID)	<input checked="" type="checkbox"/> 6A, Cold - Humid (Burlington, VT)
<input checked="" type="checkbox"/> 6B, Cold - Dry (Helena, MT)	<input checked="" type="checkbox"/> 7, Very Cold (Duluth, MN)
<input checked="" type="checkbox"/> 8, Subarctic (Fairbanks, AK)	

Graphing - Microsoft Internet Explorer

Address: <http://www.dc.lbl.gov/Labs21/Graphing.php>

LABS FOR THE 21ST CENTURY

benchmarking

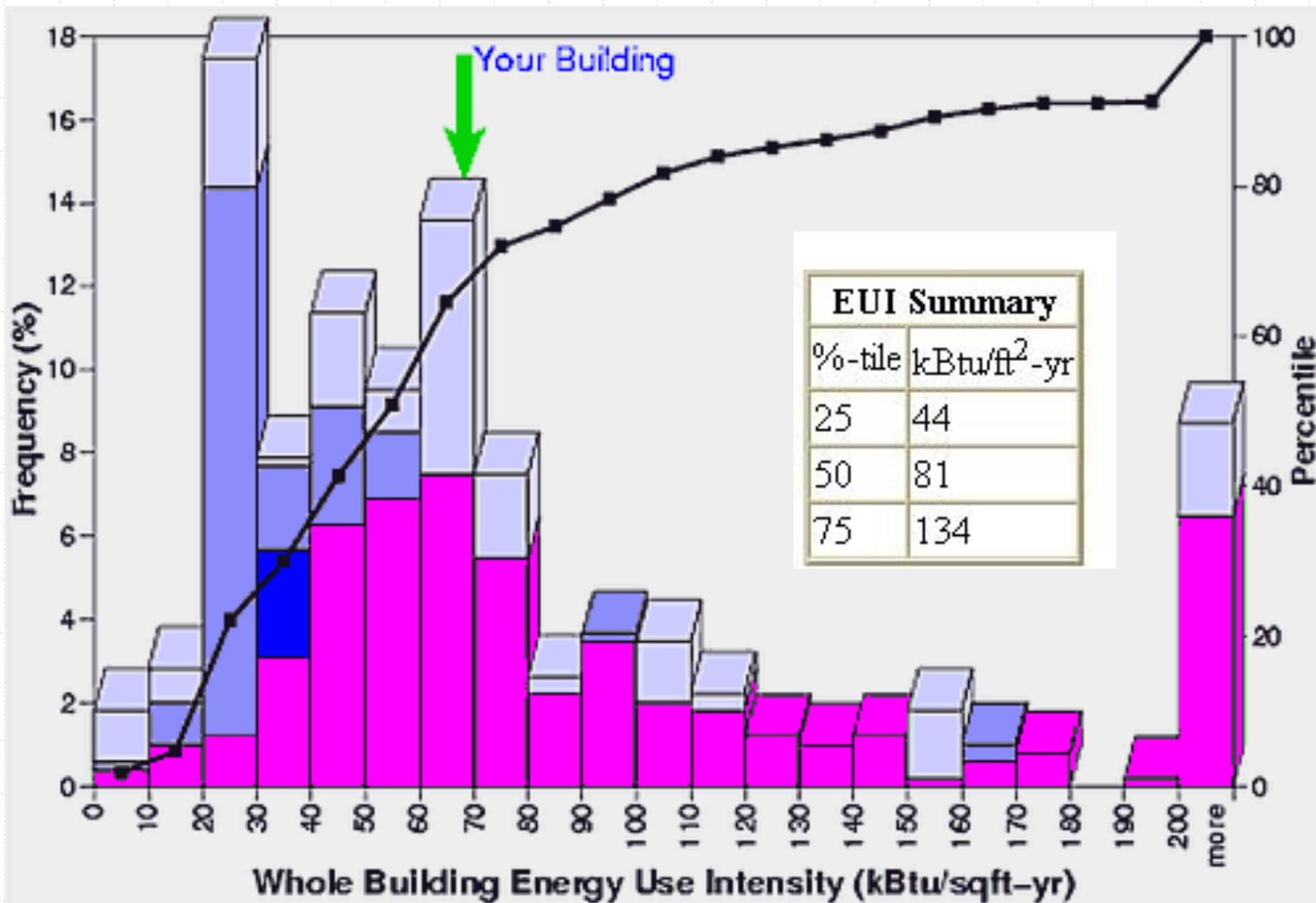
Graphing Data

User: **LBNL**
 Organization: **Lawrence Berkeley National Laboratory**

Total Building BTU/sf-yr (site)

Facility	Total Building Site Energy Use (BTU)	Gross Area (sq.ft.)	BTU/sf-yr (site)	Lab Area Ratio	Occupancy Hours	Climate
8	12613440000	54962	229493.83	0.19	12	3C
15	184866190404	532602	347100.07	0.2	11	4C
6	14396064000	55903	257518.63	0.3	12	3C
7	12350320000	44152	279722.78	0.31	12	3C
5	21098712000	85761	246017.56	0.31	12	3C
19	40723337460	151435	268916.28	0.35	12	4B
30	5108674400	21048	242843.91	0.37	24	3C

Cal-ARCH: Web-based Benchmarking



Capturing Benchmarks with Design Intent Documentation

Design Intent Tool 1.0 - [LBNL Project Template for Laboratories]

File

Introduction | Manage Project Files | Manage Template Files | User Guide | Feedback | Help | Web Home Page

Design Intent Document | Owner's Goals & Project Info | Team Contact Info | Reports

DESIGN INTENT TOOL
VERSION 1.0

Design Intent Tool 1.0
Project Name: LBNL Project Ter
Owner:
Today's Date: 08-20-2002

Select Design Area
+/- Add/Remove

- General
- Architectural: Loads
- Mechanical: Ventilation System
- Mechanical: Chiller Plant
- Mechanical: Heating Plant
- Electrical: Lighting System
- Electrical: Distribution System
- Electrical: Renewable/Distribut
- Process: Process/Plug Loads
- Operations and Maintenance

Design Area Description
This area includes whole-building information or information pertaining to multiple design areas.

Select Objective
+/- Details Click this button to add, remove or edit Objectives for this project

Objective Name	Objective Description
Achieve high overall energy efficiency	Energy efficiency is low energy consumption to accomplish a given task. High overall efficiency is low whole-building energy use (electric energy, peak electric power demand, natural gas, and any other fuels) to provide a laboratory building of a certain

Strategies
+/- Details Click this button to add, remove or edit Strategies for the Objective selected above.

Index	Strategy Name	Strategy Description
1	Exceed Title 24 requirement by factor of 2.5 (energy use 40% of Title 24 budget)	Energy code requirements can typically be easily outperformed. Such requirements make a convenient baseline against which simulated performance can be compared. Title 24 is California's State Energy Code. Buildings can comply with the Code either by the prescriptive or
2	Achieve LEED Platinum rating	The Leadership in Energy and Environmental Design (LEED) system was created by the U.S. Green Building Council to comprehensively rate buildings for their environmental impact and sustainability. Platinum is the highest rating.
3	Minimize life-cycle cost	The life-cycle cost of a building is its total cost over its entire life, including design, construction, operation, maintenance, renovation, and decommissioning; future costs are discounted to present value for comparison. Minimizing life-cycle costs usually results in higher first

Metrics
Assessment Records Click this button to view and edit Assessment Records for the Objective selected above.

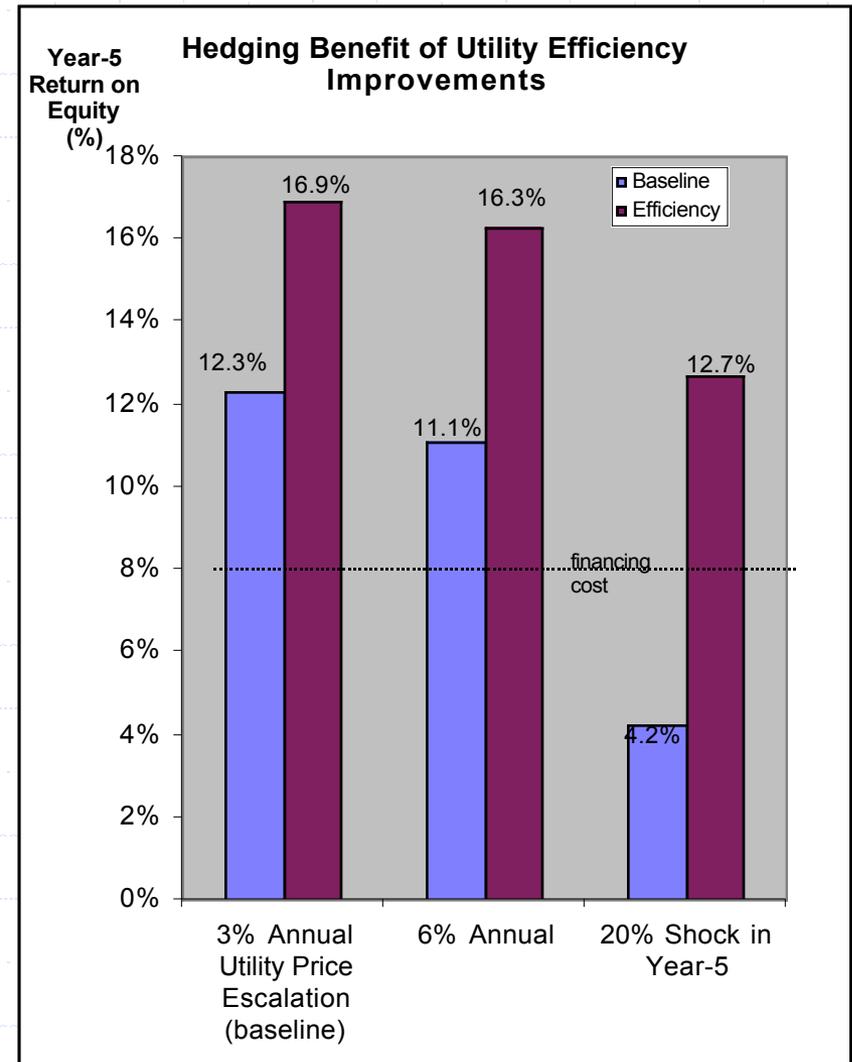
Index	Metric Name	Metric Description	Target	Units
1	Total annual kWh/sf	Whole-building electric energy use per gross square foot of building. From building electric meter.		
2	Annual source BTU/sf (combined gas and electric)	Whole-building total energy use per gross square foot of building. Source BTU/sf is calculated using XXXX BTU/kWh of electricity and a		

Approach

- ◆ Decide how benchmark is to be used
 - Choose type(s) of benchmarks
 - Define “indicators”
 - Be creative
- ◆ Measurement plan
- ◆ Clear definitions (e.g. “floor area”)
- ◆ Collect data (privacy issues)
- ◆ Establish filters & normalization methods
- ◆ Learn from “outliers”

Needs

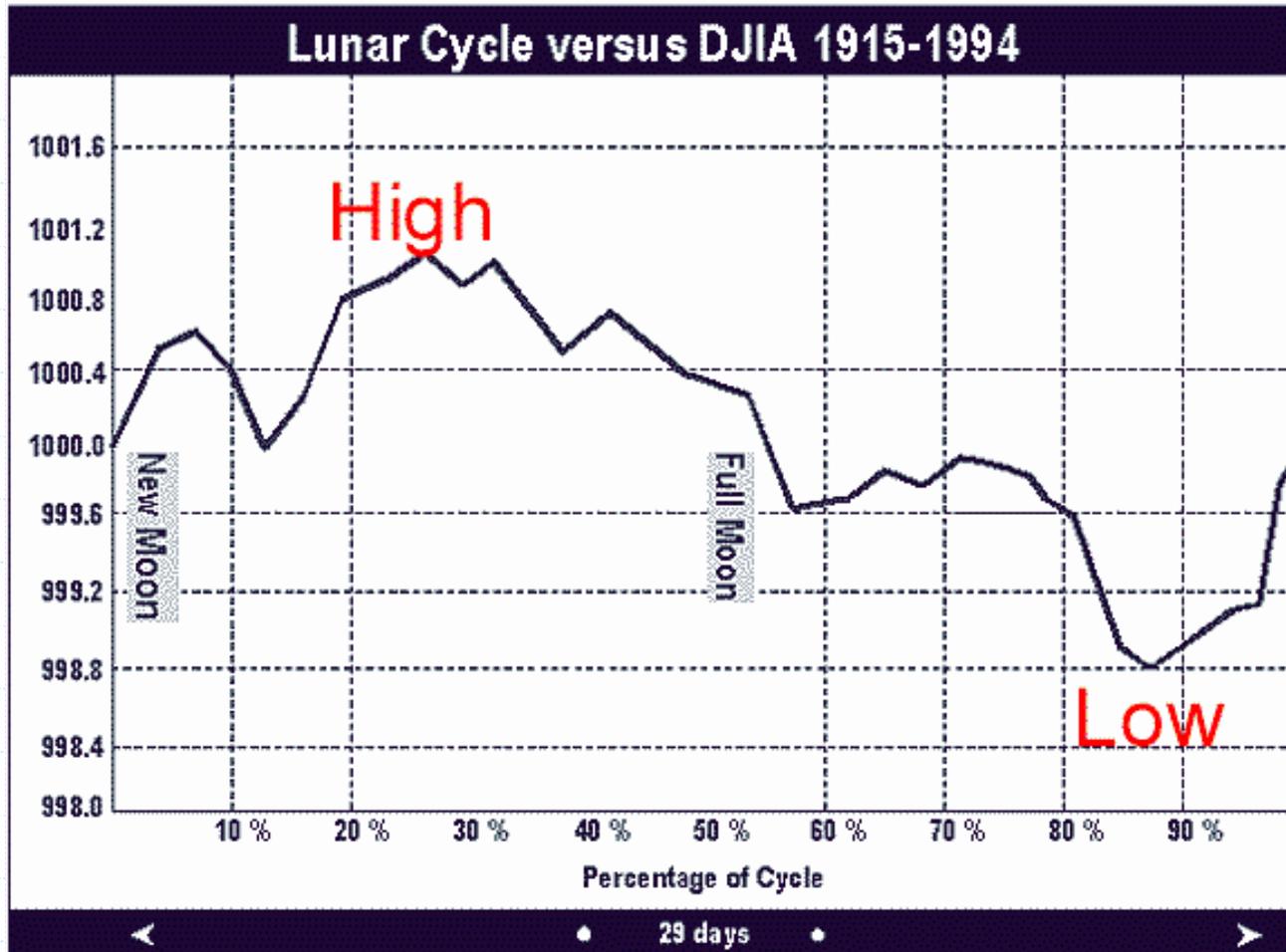
- ◆ Considerable unmet need for benchmarking presentations that bridge the “physical” and “financial”
- ◆ More focus on component or end-use benchmarking
- ◆ Growing importance of peak demand



Moral of the Story

- ◆ “To define an energy efficiency indicator is not only a technical challenge, but also a pre-structuring of the subsequent policy choice.”
 - ◆ Aebischer, et al. (2003)

Correlation is Not Causation!



Advice for Traders: “moon-trading is by no means a stand-alone approach”